

UNIT - 6

CHEMISTRY FOR CLASS IX

PERIODIC CLASSIFICATION OF ELEMENTS



राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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PREFACE

The present series of twelve chemistry units has been developed for try-out of the Individually Guided System of Instruction (IGSI) in class IX. The description of IGSI and first two units of this series of units are available under a separate cover. This new system of instruction and the units have been developed along the lines of the National Policy on Education (NPE-86) and involve the participation of pupils in the process of learning. The units are suited for self-study with occasional help from a tutor. In the present context, these units will serve as an exemplar self-study material for secondary stage chemistry. In developing this unit, I was assisted by some of the chemistry teachers.

This unit contains an introduction for motivation, arousing interest, and to link the present unit with preceding and next units. The objectives given in this unit are the expected learning outcomes, so that the pupil will know the ultimate goals he has to achieve. The suggested reading material provided in the unit guides the pupil to achieve pre-stated objectives. A number of intext and post-text questions, activities, and problems have been included to provide enough practice and chance for self evaluation.

The suggestions for the improvement of this unit will be welcomed.

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I. Introduction

The study of chemistry is important mainly because of the large number of applications of the elements and their compounds in our daily life.

Each element and compound has its own characteristic properties. Because of the existence of a large number of elements and their compounds, it is not possible to remember the characteristic properties of all of them individually. But it is possible to group the elements together and study about their general behaviour. This grouping of elements into various categories is known as classification of elements. In the present unit we shall study about the classification of elements into different groups

Such a classification of elements into a periodic table has brought order to the knowledge of chemistry of a large number of elements. After knowing the position of an element in the periodic table, one can predict its properties with considerable accuracy.

II. Objectives

After studying this unit, you should be able to :

- (i) Briefly illustrate the early attempts of classification of elements.
- (ii) Describe the long form of periodic table.
- (iii) Explain the meaning of groups and periods in a periodic table.
- (iv) Predict the variations in the following properties of elements, (a) valency, (b) metallic and non metallic character, (c) atomic radii, (d) ionisation potential, (e) electronegativity, (f) density, melting and boiling points, (g) nature of oxides.

III Suggested Reading Material

6.1 Need for classification of elements

We observe many things around us such as table, chair, stool, bench etc. made up of wooden, things made up of plastics such as bucket, mug, glass-tumbler, and the eatables such as fruits, vegetables, wheat, grams etc. we place these articles into various groups based on some of their common property of shape, size, taste or use. It is done for convenience. In the same way, as the chemists found more and more elements, it was a problem to remember the properties of all the elements individually.

By the beginning of nineteenth century, atomic masses of many elements were determined and their properties studied. It was found that there are certain elements which resemble in certain respects with other elements. Therefore it was thought that elements should be divided into a few groups in such a way that elements in the same group have similar properties. Let us take the examples of some elements and their compounds where some resemblances were observed. It was found that sodium and potassium resemble each other in many respects. Similarly nitrogen and phosphorus were found to show a marked chemical resemblance, as shown in table 6.1

TABLE 6.1

<i>Property</i>	<i>Sodium</i>	<i>Potassium</i>
Valency	univalent	univalent
Nature of oxide	Na_2O (basic oxide)	K_2O (basic oxide)
Nature of Hydroxide	NaOH (strong alkali)	KOH (strong alkali)
Nature of Carbonate	Na_2CO_3 soluble in water (alkaline)	K_2CO_3 soluble in water (alkaline)

Property	Nitrogen	Phosphorus
Valency	5,3	5,3
Nature of oxide	N_2O_5 (strongly acidic)	P_2O_5 (strongly acidic)
Nature of hydride	NH_3 (basic)	PH_3 (acidic)
Nature of chloride	NCl_3	PCl_3

6.2 Early attempts for Classification of Elements

First of all the classification of elements was done in two groups (I) metals, and (II) non metals. This division of elements into two broad groups was done by Lavoisier. In this classification there was no place for the elements which have properties of both metals and non metals. In 1839, Dobereiner found that when elements were arranged in the order of increasing atomic masses in groups of three elements (known as triads), the elements in a triad had similar properties. In the triad, the atomic mass of the middle element is almost equal to the mean of the atomic masses of the other two elements. For example, lithium, sodium, and potassium is one such triad. The properties of these three elements are similar. Another similar example of a triad having similar chemical properties is chlorine, bromine, and iodine.

Table—6.2

Elements of the triad	Atomic mass
Lithium (Li)	7
Sodium (Na)	23 (Atomic mass of Na = $\frac{7+39}{2} = 23$)
Potassium (K)	39
Chlorine (Cl)	35.5
Bromine (Br)	80 = $\frac{\text{Atomic mass of Br } 35.5 + 127}{2} = 81.2$
Iodine I	127

But this classification was also found unsuitable because all the elements could not be arranged in triads.

Then in 1864 Newlands arranged the known elements in the order of increasing atomic masses and found that the properties of every eighth element resembled very closely the properties of the first element. This repetition was just like the octave of music. So the statement was known as the law of Octaves,

Newland's classification of elements

Element	Lithium	Beryllium	Boron	Carbon	Nitrogen	Oxygen	Fluorine
Symbol	Li	Be	B	C	N	O	F
Atomic mass	7	9	11	12	14	16	19

Element	Sodium	Mageni- sum	Alum- inium	Silicon	Phos- Phorus	Sulphur	Chlorine
Symbol	Na	Mg	Al	Si	P	S	Cl
Atomic mass	23	24	27	28	31	32	35.5

Element	Potassium	Calcium	Titanium	Chromium
Symbol	K	Ca	Ti	Cr
Atomic mass	39	40	48	51

The properties of lithium, sodium, and potassium were found to be the same. Sodium is the eighth element from lithium, potassium is the eighth element from sodium. Similarly Mg and Ca resemble with each other.

Questions

1. What is the need to classify elements ?
2. A, B, and C are the members of a Dobereiner's triad. If the atomic mass of A is 9 and that of C is 40, what is the atomic mass of B ?
3. What is the Newland's law of octaves ? How far Newlands succeeded in the classification of elements ?

6.3 Mendeleev's Classification of Elements

Mendeleev developed the further idea of classification of elements. When elements are arranged in the order of increasing atomic masses, the elements with similar properties appear at regular intervals. Based on this observation he gave a periodic law which states that properties of the elements are a periodic function of their atomic masses. He arranged the elements in the horizontal rows (known as periods) in order of increasing atomic masses and in vertical columns (known as groups) each containing elements of similar properties. There were seven periods (horizontal rows) and eight groups (vertical columns) in his periodic table

Mendeleev's classification of elements was a great help in the study of elements. However a few anomalies, could not be explained on the basis of Mendeleev's periodic law. These are given below ;

- I. *The position of isotopes could not be explained* : If the elements are arranged according to atomic masses, the isotopes should also find some place in the periodic table. For example, Cl_{35} and Cl_{37} . Both should find some place in periodic table. But it was not so
- II. *Wrong order of the atomic masses of some elements* : For example argon (Ar, Atomic mass 40) comes before potassium (K, atomic mass 39) Tellurium (Te, atomic mass 127.6) comes before iodine (I, atomic mass 126.9).

6.4 Modern Basis of Classification

After Moseley's work (1913) on the experimental determination & atomic number, it was thought that the atomic number of an element is a more fundamental property than its atomic mass. As no two elements have same atomic number, it was considered a more suitable base for classification of elements. According to this, periodic law given by Mendeleev was also modified. The modern periodic law states that the *properties of the elements are periodic function of their atomic numbers*. The modified form of periodic table based on atomic numbers removed all drawbacks which were present in Mendeleev's Table. When the elements are arranged in order of their increasing atomic numbers, the problem of placing the isotopes does not arise.

Long form of Periodic Table

A popular form of periodic table known today is the long form periodic table. The classification of elements in the long form of periodic table is based on their electronic configuration. In this, the elements have been arranged in the increasing order of atomic numbers. The elements are grouped in four blocks : s-block, p-block, d-block, and f-block based on their electronic configurations. These blocks are divided into vertical groups. Apart from groups there are also horizontal rows called periods.

This periodic table has seven periods numbering from 1 to 7. Hydrogen and helium constitute period 1, period 2 begins with lithium and has eight elements ending with neon. Third period begins with sodium. Sodium resembles closely with lithium in the same group. This period also contains eight elements. Such periods of eight elements are known as *short periods*.

Fourth period starts with potassium and contains 18 elements ending with the noble gas krypton. Fifth period also has 18 elements as in the fourth period. It starts from element rubidium and ends with noble gas, xenon. Each of the elements in the fifth period closely resembles the elements above it in the preceding periods. These periods are known as *long periods*.

Sixth period in the periodic table has 18 elements just as in the fourth and the fifth periods. In addition, it has 14 more elements lying between lanthanum, atomic number 57 and hafnium, atomic number 72. These 14 elements constitute a group-known as the lanthanides and are placed at the bottom of the periodic table. Sixth period consists of 32 elements and is therefore, called as *very long period*.

The seventh period is still incomplete as some of the later elements have not been discovered as yet. We can go upto the element with atomic number 105. The elements starting with actinium, atomic number 89 and onwards are known as the actinides or actinide series. A summary of the total number of periods in the periodic table and the total number of elements present in each period is provided in Table 6.3.

d-block

↑
↑
↑

6

d-block

f-block

TABLE - 6.3

Periods	Total number of elements	From	to
1	2	H	He
2	8	Li	Ne
3	8	Na	Ar
4	18	K	Kr
5	18	Rb	Xe
6	32	Cs	Rn
7	19	Fr	Lw.

Questions

1. State the periodic law on which Mendeleev's periodic table was developed.
2. State the drawbacks of Mendeleev's classification of elements ?
3. Give answers of the following questions in one word.
 - (a) What is the name given to horizontal rows in the periodic table ?
 - (b) What is the name given to vertical columns in the periodic table ?
 - (c) How many periods are there in the long form of periodic table ?
 - (d) What is the number of elements present in the fourth period ?

Gradation in properties in groups and periods

(a) Valency

The valency is determined by the number of valence electrons present in the outermost shell of the atom of an element. On moving from left to right in a period the number of valence electrons increases

from one to eight (in the first period it increases from one to two). Let us write the electronic configurations of the third period elements to make it clear. The number of valency electrons increases from one in sodium, Na, to eight in argon, Ar. If we examine the long form of periodic table, we find that in case of s-and p-block elements, number of a group is same as the number of valence electrons. For example, chlorine has seven electrons in its outermost shell and placed in the VIIth group. But noble gases have 8 electrons in their zero group. Valency of such elements is equal to the group number (G) or 8 minus the group number (8-G). For example, carbon in IVth group has valency 4, chlorine in VIIth group has $(8-7=1)$ valency one. This is not true in case of d-block elements.

Elements	Na	Mg	Al	Si	P	S	Cl	Ar
Electronic	K L M	K L M	K L M	K L M	K L M	K L M	K L M	K L M
Configurations	2 8 1	2 8 2	2 8 3	2 8 4	2 8 5	2 8 6	2 8 7	2 8 9
Valency	1	2	3	4	5	2	1	0

All the elements of a particular group have the same number of valence electrons. For example, group I elements have one electron each in their valence shells. Group VII elements have seven electrons each in their valence shells.

Since the number of valence electrons in a group is the same, all the elements of the group have the same valency :

Group I	Electronic configuration	No. of valence electrons	Group VII	Electronic configuration	No. of valence electrons
Li	2, 1	1	F	2, 7	7
Na	2, 8, 1	1	Cl	2, 8, 7	7
K	2, 8, 8, 1	1	Br	2, 8, 18, 7	7
			I	2, 8, 18, 18, 7	7

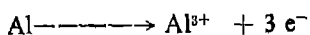
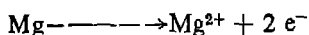
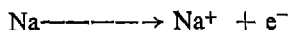
(b) Metallic Character

On moving from left to right in a period, the metallic character of the elements decreases and the non metallic character increases. On the left side of the periodic table we have metals and on the right side, non-metals. For example let us examine the elements of third period of the table.

Third period	Na	Mg	Al	Si	P	S	Cl
Nature	Metals			Metalloid		Non-Metals	

The elements lying between metals and non-metals are known as metalloids.

A metal is characterised by its tendency to give up electrons to form positively charged ion and a non-metal by its tendency to gain electrons to form negatively charged ion. The elements Na, Mg, and Al have 1 to 3 electrons in their outermost shells. They have eight electrons in their penultimate shells. Therefore they can lose 1, 2, & 3 electrons respectively and form positively charged ions.



Therefore these elements show metallic character. They are called *electropositive* elements. But if we take the case of chlorine, it has 7 electrons in its outermost shell. It means, one electron less than the nearest noble gas configuration. Therefore it prefers to gain one electron and get converted into negatively charged ion. It is a non metal and is also called, *electronegative element*.

In a group, electropositive character increases from top to bottom. For example group IV consists of non metal, carbon, and tin and lead as metals (table - 6.5)

Group IV	Acc. No. <u>FL700</u>	Nature
Carbon (C)	Date. <u>5.9.88</u>	Non-metal
Silicon (Si)		Metalloid
Germanium (Ge)		Metalloid
Tin (Sn)		Metal
Lead (Pb)		Metal

When we proceed from top to bottom in a group, we find that the number of shells increases and as a result the distance of the electrons present in the outermost shell from the nucleus also increases. Due to this increase in distance the electrons from the outermost shell can be withdrawn easily as compared to the electrons close to the nucleus. Thus the ease of removal of electrons from an element makes it more electropositive and hence more metallic.

(C) *Atomic radius* : The distance between nucleus of an atom and its outermost shell is known as atomic radius. Atomic radii decrease in going from left to right in a period. In going across a period the electrons are added to the same shell without the addition of any new shell. Thus the nuclear charge increases without the addition of a new shell. Due to an increase in positive and negative charges, the electrons are attracted towards the nucleus to a greater extent and atomic radius decreases. For example in second period the nuclear charge increases from + 3 in lithium to + 9 in fluorine without adding another shell. Atomic radii change from 1.23 Å° for Li to 0.72 Å° for F.

Second period	Li	Be	B	C	N	O	F
Atomic radius (Å°)	1.32	0.90	0.82	0.77	0.75	0.73	0.72

Atomic radii increase on going down a group. This increase in radii is due to the presence of increasing number of electron shells. For example in 1st group, lithium has two shells,

K and L, whereas sodium atom has K, L, & M three shells. Therefore sodium atom is lighter than lithium atom. (The decrease in size due to increased attraction between electrons and nucleus is much less as compared to the increase in size due to addition of an extra shells of electrons).

Group I	Atomic radii (Å) ^o
Li	1.23
Na	1.54
K	1.96

(D) *Density, melting point and boiling point* : If we go across the period from left to right, the density increases and reaches a maximum value somewhere in the middle. Melting and boiling points follow the same trend.

On going down a group the melting and boiling points decrease. There is however a regular change (gradation) in their reactivity and physical constants like melting and boiling points. The melting points of lithium, sodium and potassium show a gradual decrease.

Group I Elements	Melting point
Li	180.5°C
Na	97.5°C
K	63.4°C

IV Home Assignment

Questions

1. Give a brief outline of the attempts made to classify elements.
2. What criterion of classifying elements was adopted by Mendeleev ? What is meant by the statement "Properties of elements are periodic function of their atomic numbers ?"

3. Compare elements of group IA with elements of group VII A with regard to their atomic radii, electronic configuration and valency.
4. What is the fundamental difference in the electronic configuration between the group IA and group IIA elements.
5. Elements A,B,C, & D have n electrons each in the outermost shells of their atoms. Giving reason, state whether they belong to the same period or the same group of the periodic table.
6. What are electropositive and electronegative elements? Explain the differences with examples.

V Self Assessment

Questions

1. Compare Mendeleev periodic table with long form of the periodic table.
2. In each of the following pairs, State which one is larger in size :-
(a) C, Si (b) Br, I (c) Li, C (d) Li, Na (e) Cl, Br (f) Be, Mg
you may consult Periodic Table.
3. Take help of the periodic table and distribute the following elements in :- s, p and d block elements
Na, Mg, Cr, Ni, Al, Cu, Cl, Ag, Mn, S, Se, Hg, P, N
4. For each of the following binary compounds, state whether each element has valence (i) equal to the group number, (ii) eight minus group number or neither of the two
(a) CaCl_2 (b) PCl_5 (c) NaCl (d) SF_6 (e) MgS (f) CS_2 (g) AlP (h) SO_2 (i) PCl_3 .
5. Chemically metals are characterized by their tendency to give up electrons to form positively charged ions and are referred to as electropositive elements. On the other hand, non metals tend to gain electrons and are referred to as electronegative elements. Classify the following elements into electropositive and electronegative elements.

Ca, Cl, Al, Br, K, F, Na, I

6. What is the atomic number of the next element which is in the same group to which the element A belongs? (at. no of A=7).
7. Atomic radius increases with increase in atomic number in
- A. a group
 - B. a period
 - C. both a group and a period
 - D. neither a group nor a period.
8. Electronegative character increases, with increase in atomic number in
- A. a group
 - B. a period
 - C. both a group and a period
 - D. neither a group nor a period.
9. Based on their location in the periodic table, classify the following elements as metals, non-metals and metalloids.
lithium, carbon, silicon, argon, lead and fluorine.
10. In terms of outer electrons how do the halogens differ from the Group I elements.
11. Metallic character increases, with increase in atomic number in
- A. a period
 - B. a group
 - C. both a group and a period
 - D. neither a group nor a period
12. In PCl_5 , phosphorus has a valency equal to
- A. its group number
 - B. eight minus group number
 - C. its period number.

Teacher's Guide

Classification is an important step in learning and understanding the behaviour of any object. There are 105 known elements. Many more are yet to be discovered. Therefore, there was a need to arrange them systematically in order to facilitate their study. The earlier basis of classification was *atomic mass* of elements. It has now been replaced by *atomic number*. The Periodic Table has divided the elements into horizontal rows (Periods) and vertical columns (groups).

The physical and chemical properties of elements show a regular change in periods and groups called gradation of properties. In this unit, the students study about the classification of elements and familiarise themselves with gradation of properties. You may start this unit with a student-activity in which they may be asked to classify a number of given objects (for example wooden pieces with different shapes and colours) on the basis of some observable property, colour and shape. The need for classification of elements may be related with this activity. The long form of periodic table may be shown in the class. The variation in properties may be explained.

Suggested activity

1. Drawing of the chart of long form of the periodic table.
2. Classification of elements in broad divisions like metals and non-metals.